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GB 1363761
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G2F

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(54) Liquid crystal display cell

(57) When the lead electrodes which provide connections to transparent display electrodes 12 of a liquid crystal display device are extremely narrow, e.g. 30μ or less, their resistance may be reduced to an acceptable value if they are formed of a thin film metal layer 16 overlaid by an equal width of transparent material 42 integral with the electrode 12. Leakage current is prevented from flowing between adjacent lead electrodes (spacing of 30μ for example) by providing a transparent insulating layer 40 over and between them.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

Fig. 10

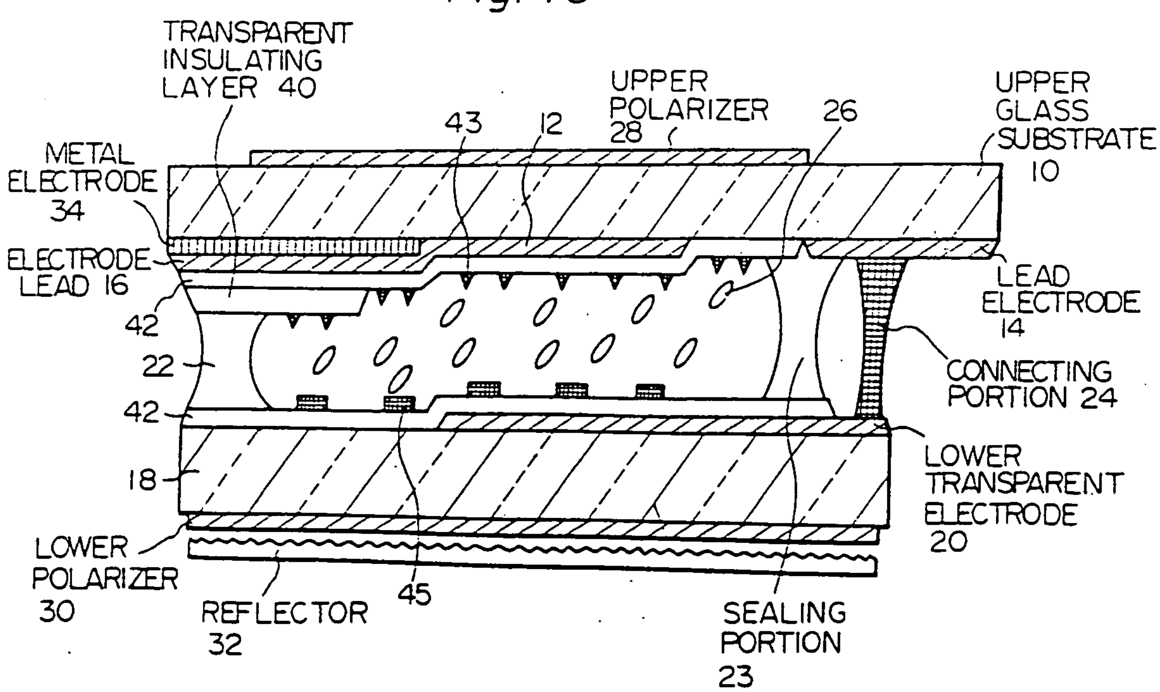

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Fig. 1
PRIOR ART

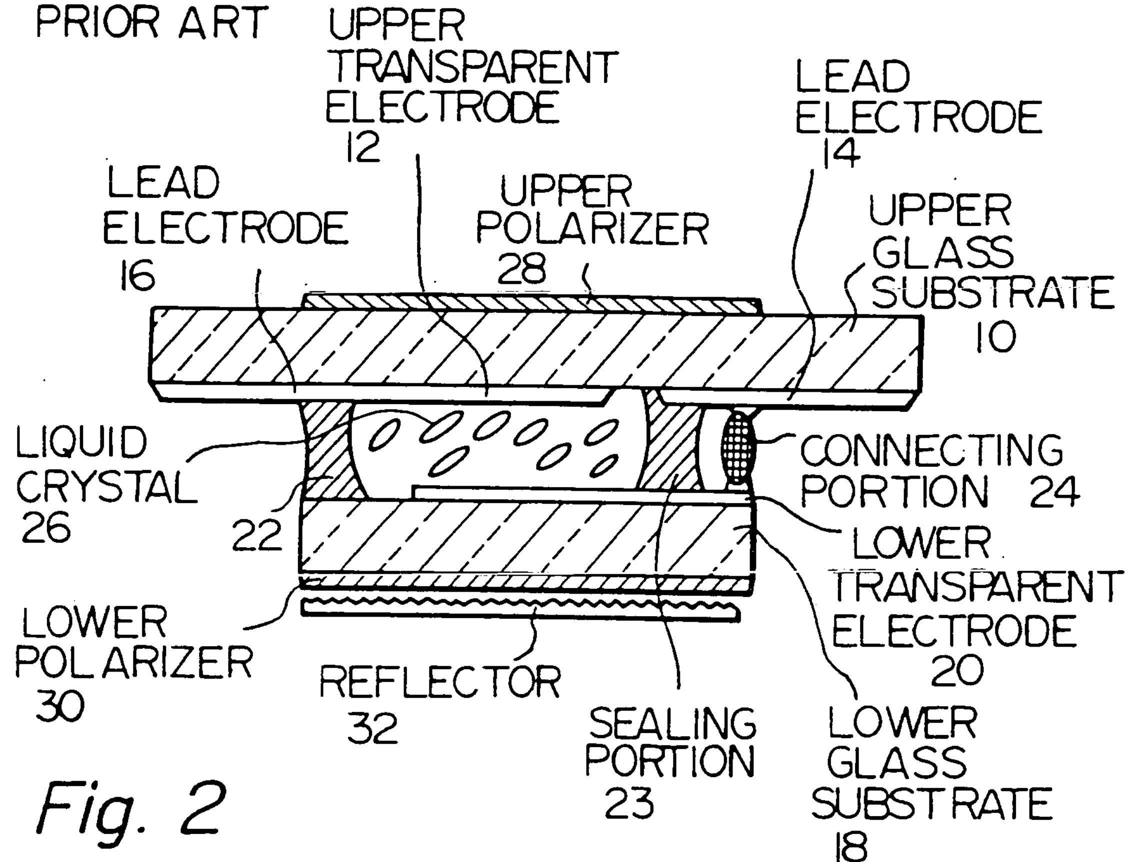

Fig. 2
PRIOR ART

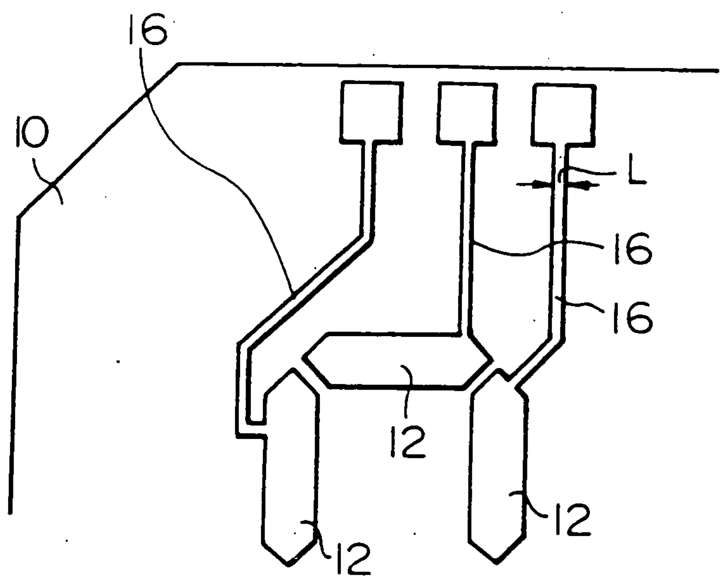

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Fig. 3

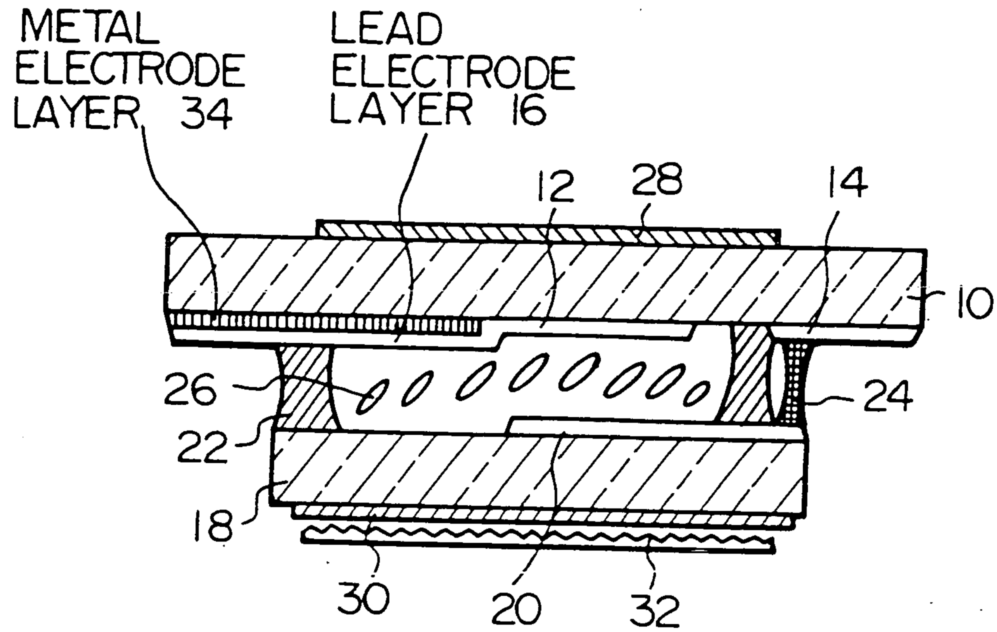

Fig. 4

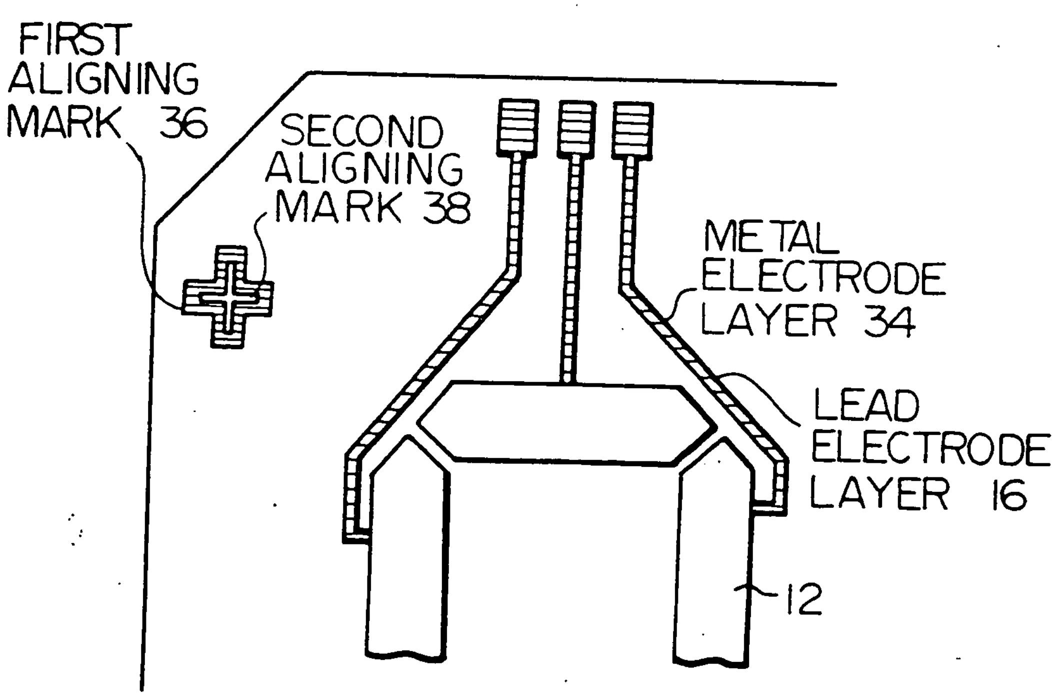

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Fig. 5

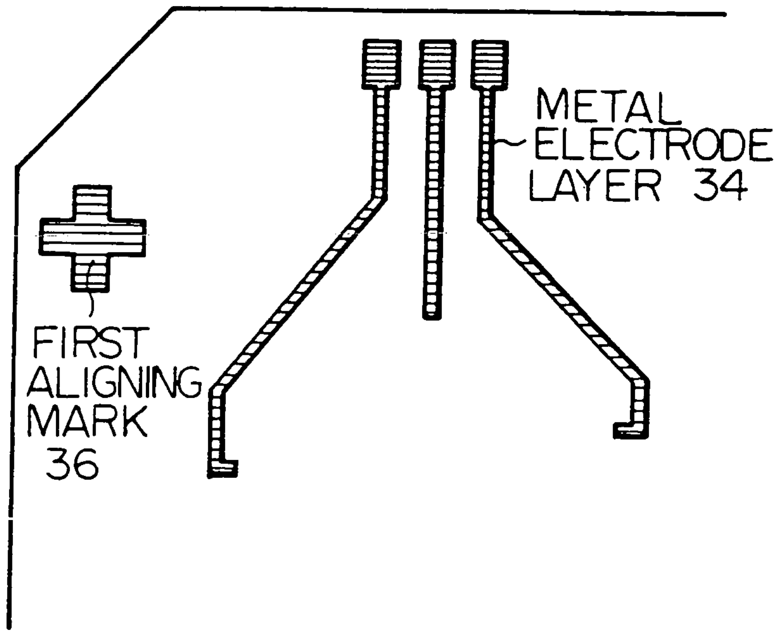

Fig. 6

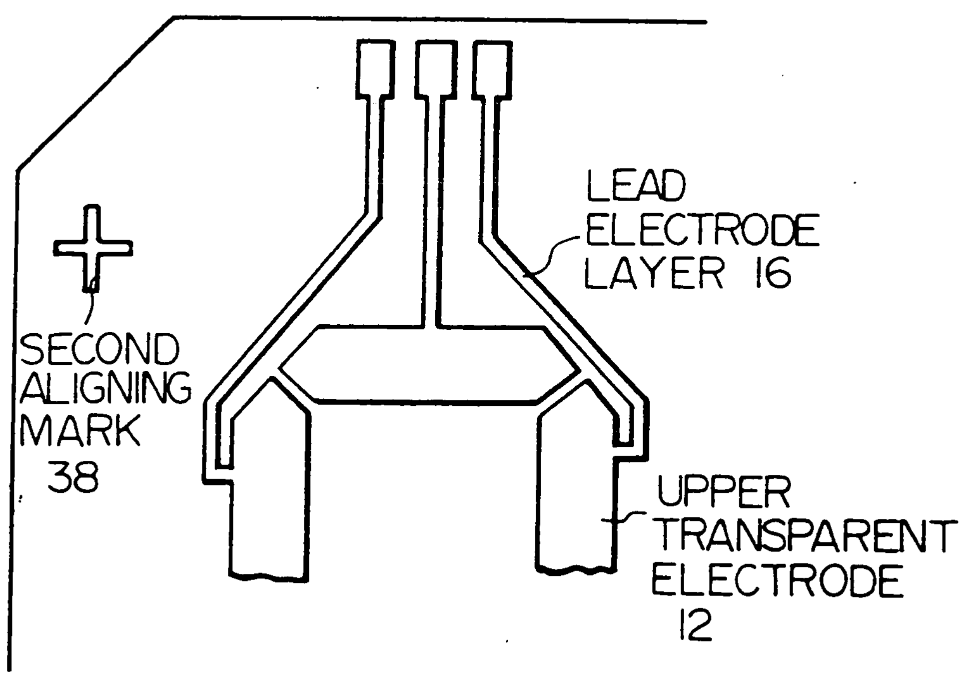

Fig. 7

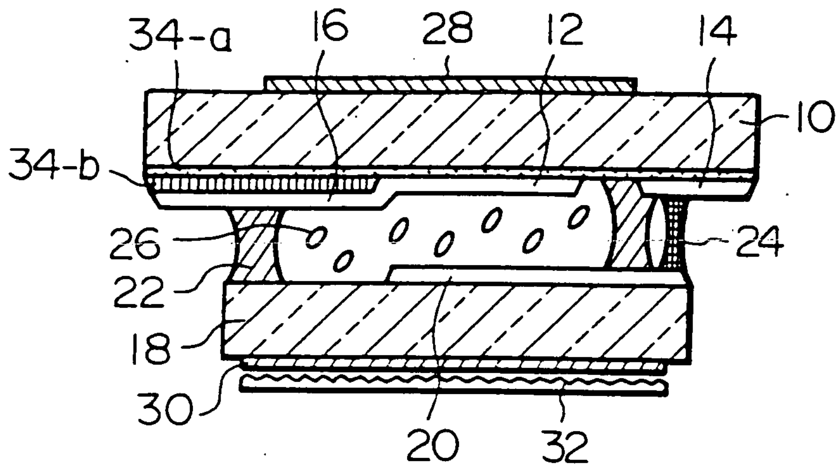

Fig. 8

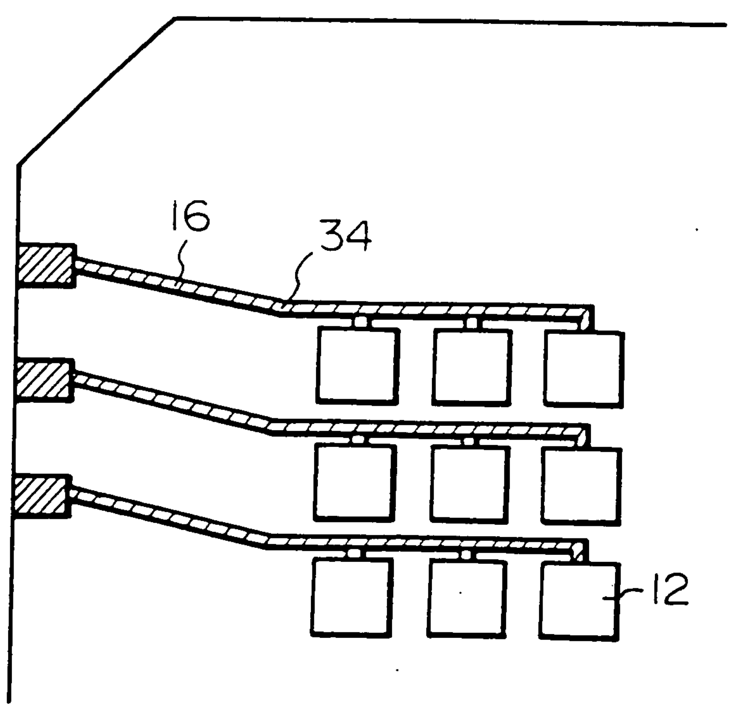

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Fig. 9

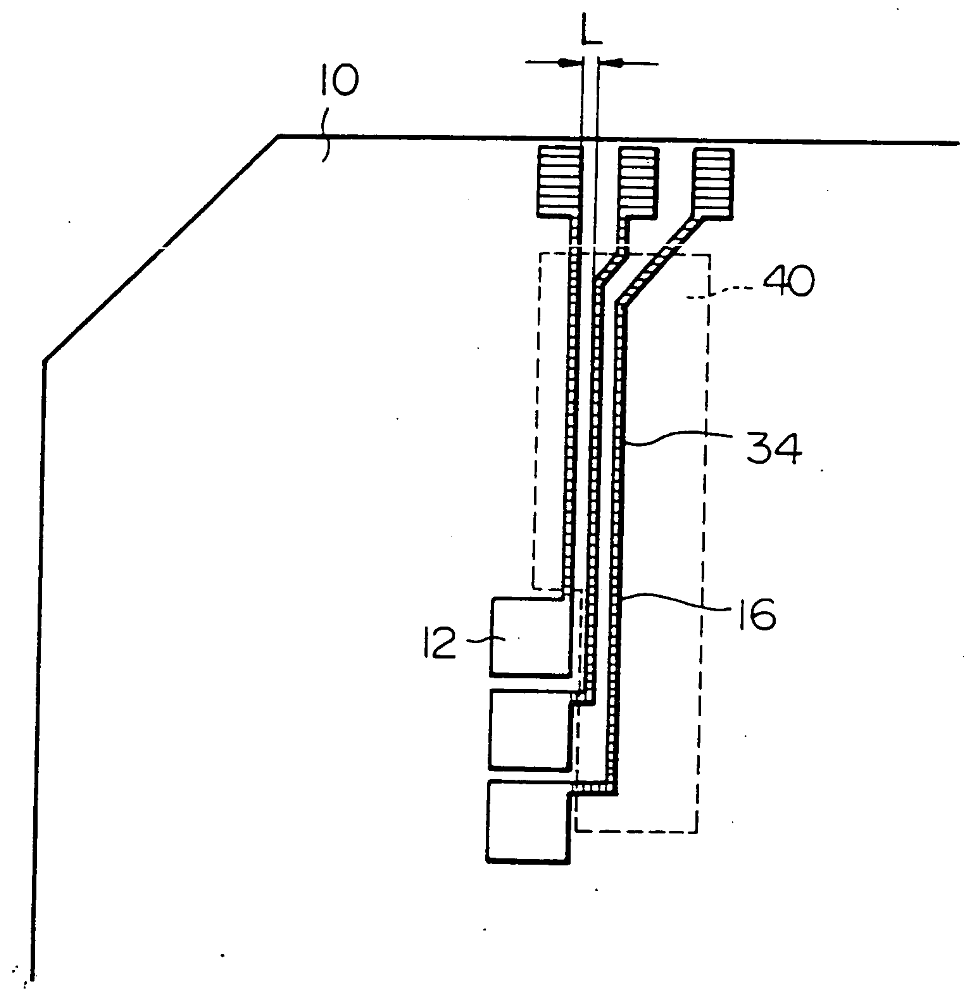


Fig. 10

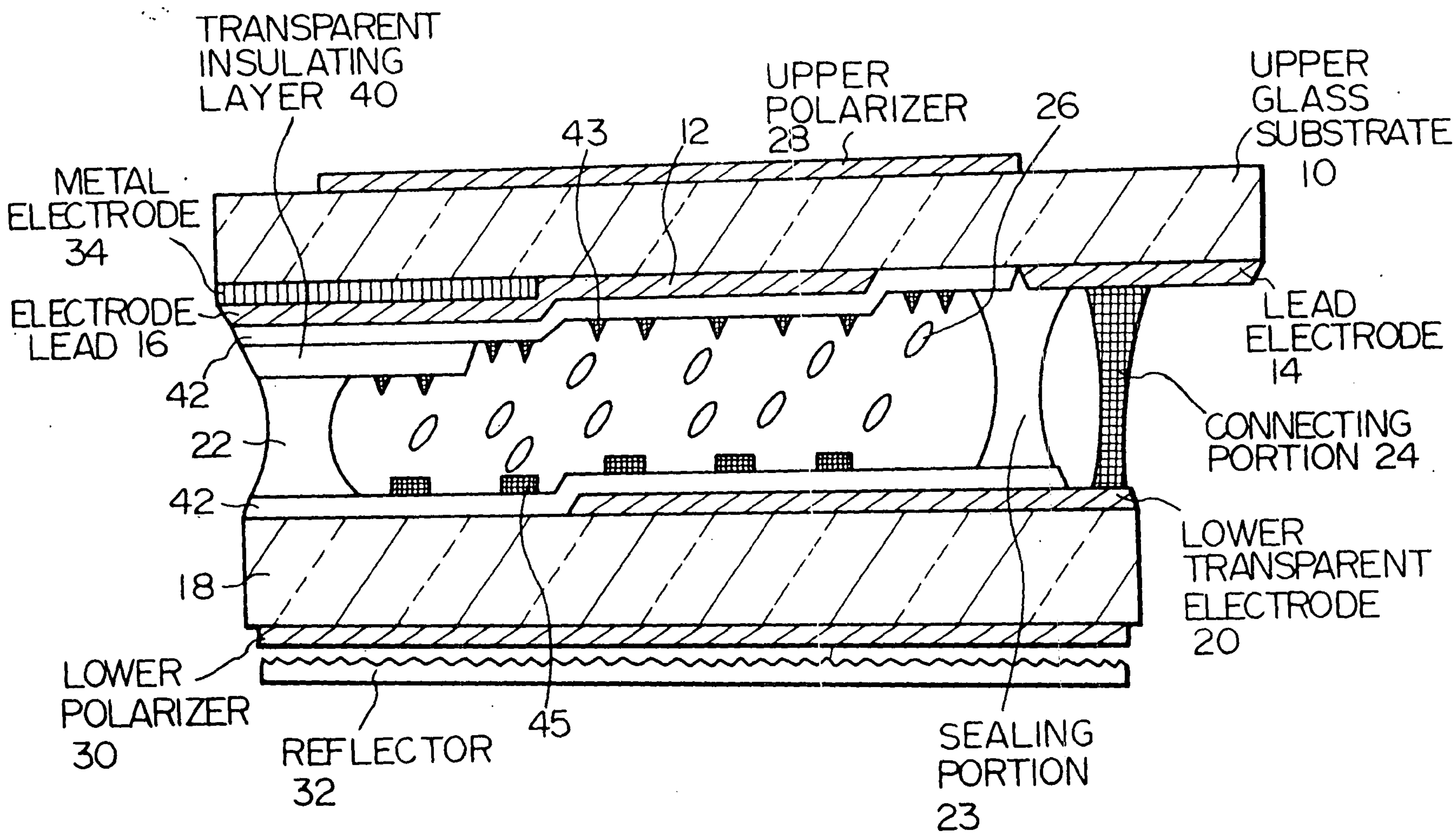

TRANSPARENT INSULATING LAYER 40
UPPER POLARIZER 28
26
UPPER GLASS SUBSTRATE 10
43
12
METAL ELECTRODE 34
ELECTRODE LEAD 16
42
22
42
18
LEAD ELECTRODE 14
CONNECTING PORTION 24
LOWER TRANSPARENT ELECTRODE 20
LOWER POLARIZER 30
REFLECTOR 32
45
SEALING PORTION 23

Fig. 11A

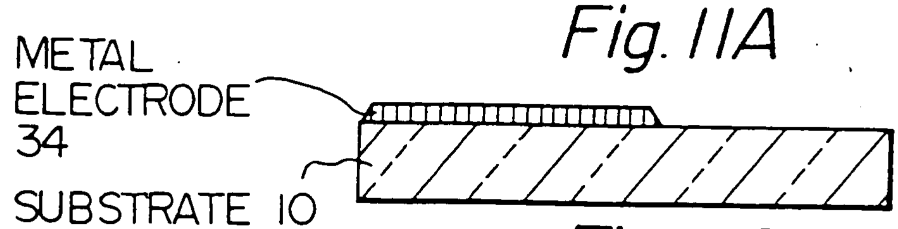


Fig. 11B

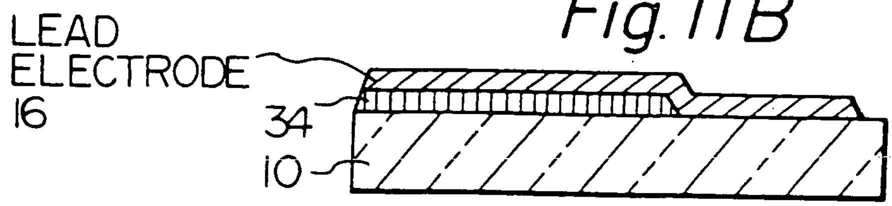


Fig. 11C

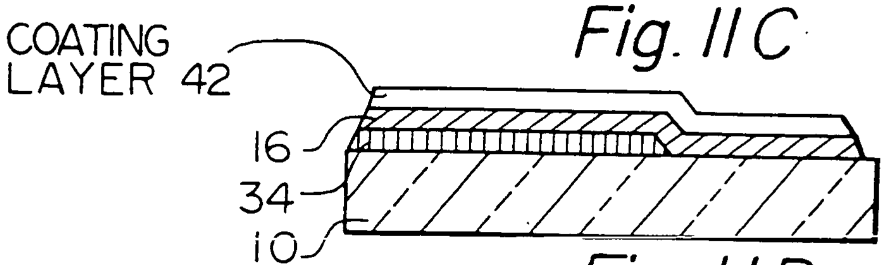


Fig. 11D

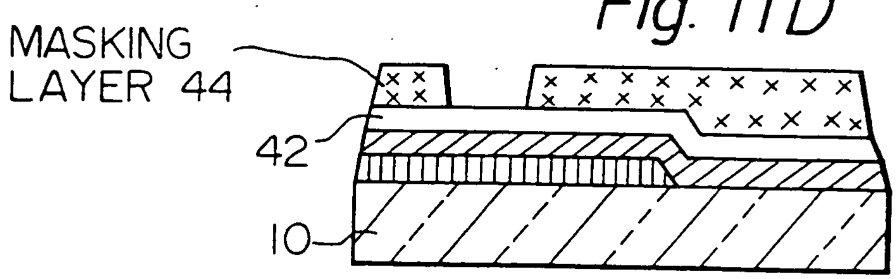


Fig. 11E

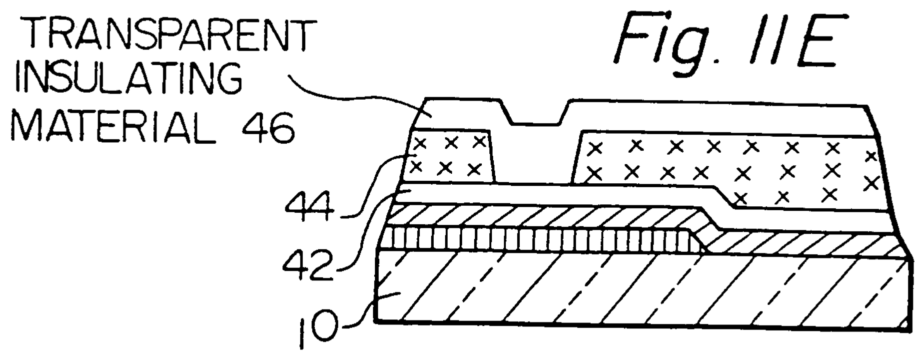


Fig. 11F

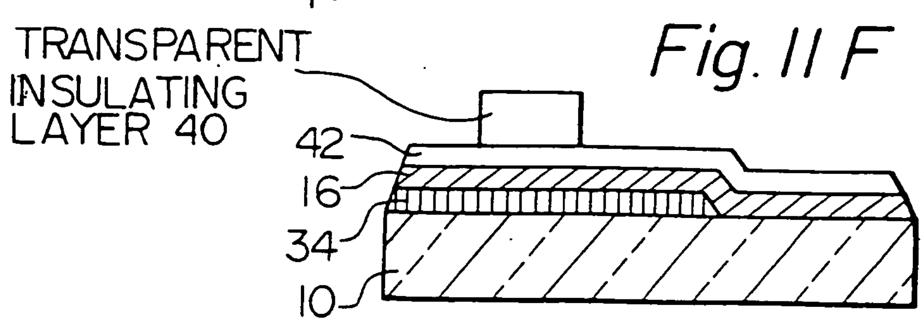
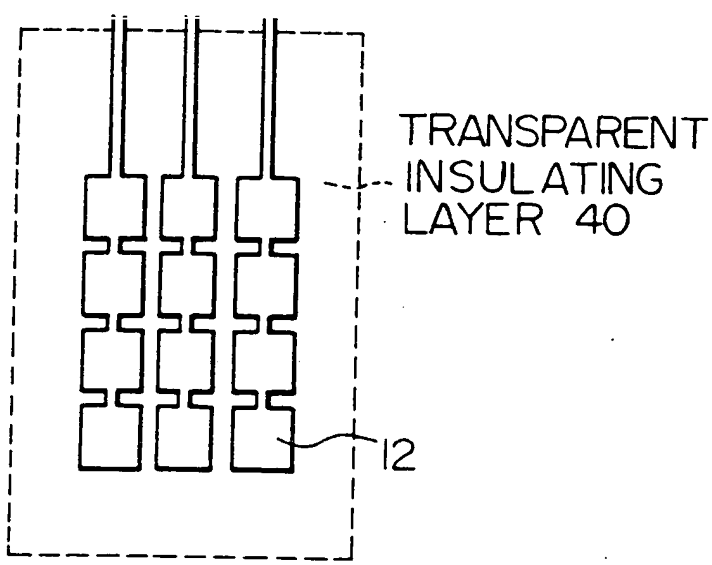


Fig. 12



SPECIFICATION

Liquid crystal display cell

BACKGROUND OF THE INVENTION

At the present time, liquid crystal display devices are widely used in a variety of electronic equipment. In particular, liquid crystal display devices are extensively used in applications where the display area size is relatively small, while various types of information must be displayed in the display area when the equipment is switched to various different operating modes. Such applications include, for example, electronic timepieces having a number of different functions, and combined electronic timepiece/calculator devices. In such an application, due to the very large number of connections which must be made to the display electrodes of the liquid crystal display device, the density of the connecting leads provided on the liquid crystal cell substrates for connecting to the display electrodes becomes extremely high. (Such connecting leads are commonly referred to as lead electrodes, and are so designated hereinafter.) Thus, in order to accommodate a requisite number of lead electrodes on a given area of liquid crystal cell substrate, it becomes necessary to reduce the width of each lead electrode, and to reduce the spacing between the lead electrodes. This however results in several adverse effects. The lead electrodes are normally formed in the same way as the display electrodes, i.e. by evaporative deposition, and have the same thickness (i.e. measured in a direction normal to the substrate plane) as the display electrodes, which are usually sufficiently thin to be transparent. Thus, as the width of the lead electrodes is decreased, their electrical resistance increases. This effect becomes particularly noticeable when a lead electrode made of a thin film of a commonly-used material such as indium oxide (In_2O_3) or thin oxide (SnO_2) is reduced to a width of the order of 30 microns or less. The resultant increase in lead resistance may cause some areas of the display to have significantly reduced contrast, by comparison with other areas in which the lead electrode resistance is at a more normal value. Thus, areas of uneven display contrast may result. If the lead electrode resistance becomes excessively high, then failure of parts of the display may result. It can therefore be appreciated that the problem of excessively high resistance of lead electrodes in a liquid crystal display device having a very high density of lead electrodes on the cell substrates is serious, and that some method of alleviating this problem is desirable.

Another problem which arises in this respect is due to the lead electrodes being spaced very closely together. Due to this small separation between adjacent lead electrodes, leakage current can flow between them, and this can cause problems such as unwanted activation of certain areas of the display. In other words, display segments which should be in an "off" state may electrodes is reduced to the order of 30 microns or less.

SUMMARY OF THE INVENTION

According to the present invention, there is provided in a liquid crystal display cell composed of two transparent supporting substrates arranged parallel to one another, sealed together peripherally to form an enclosed chamber containing a liquid crystal material, and having a transparent display electrode formed on an inner face of at least one of said transparent supporting substrates composed of a thin film of an electrically conductive substance and a lead electrode provided on said inner substrate face for providing electrical connection between said transparent display electrode and external drive means, the improvement comprising a multi-layer construction for said lead electrode for thereby reducing the electrical resistance thereof, said multi-layer lead electrode construction comprising a metallic electrode layer of a metallic substance formed on said inner substrate face and a lead electrode layer formed over said metallic electrode layer, said lead electrode layer being formed integrally with said display electrode and having a width which is substantially equal to the width of said metallic electrode layer, measured in a direction parallel to the substrate plane.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Fig. 1 is a cross-sectional view of a liquid crystal display cell having a construction known in the prior art;

Fig. 2 is a plan view of the lead electrodes and display segment electrode structure of part of a liquid crystal display cell of the type shown in Fig. 1;

Fig. 3 is a cross-sectional view of a first embodiment of a liquid crystal display cell according to the present invention;

Fig. 4 is a plan view of the lead electrodes and display segment electrodes of part of the liquid crystal display cell embodiment of Fig. 3;

Fig. 5 is a plan view of the lead electrode structure of the first embodiment of Fig. 3, illustrating a manufacturing stage at which a metallic electrode layer is formed;

Fig. 6 is a plan view of the first embodiment, illustrating a manufacturing step in which a transparent segment electrode and lead electrode layer is formed;

Fig. 7 is a cross-sectional view of a second embodiment of a liquid crystal display cell according to the present invention, in which a layer of chromium is deposited beneath the metallic electrode and lead electrode layers;

Fig. 8 is a plan view of part of the lead electrode and display electrode structure of a third embodiment of the pr sent invention, in which display electrodes are in the form of a dot matrix array;

is used, a mask plate is provided around the periphery of the display area in order to conceal wiring connections, etc. It will usually be possible to conceal the lead electrodes by such a mask, wholly or partially, so that the visibility of the lead electrodes does not present a significant problem.

Fig. 4 is a plan view of part of the display cell of Fig. 3, showing the lead electrode arrangement. Numerals 36 and 38 denoted aligning marks, which are used in forming the multi-layer lead electrodes. Such aligning marks are necessary due to the very small width of the lead electrodes.

The manufacturing process for forming transparent display electrodes (i.e. segment electrodes 12 of Fig. 4) and multi-layer lead electrodes in accordance with the present invention will now be described. It will be assumed that a metal electrode layer consisting of a layer of chromium and a layer of gold is used. However, it is also possible to utilize various other conductive materials to form the metal electrode layer. In the first stage, a layer of chromium is formed over the entire surface of a glass substrate, by evaporative deposition or by sputtering. A thin film of gold is then formed over the chromium layer. A photo-resist material is then formed over the gold film, by a spinner method, and the desired pattern of lead electrodes is formed in the photo-resist by exposure to light and development. The unnecessary portions of the gold film and chromium layer are then removed by etching. The gold film may be etched by aqua regia, and the chromium layer etched by a mixture of perchloric acid, cerium nitrate ammonium and water, in the proportions 10 ml: 20 grams: 500 ml, respectively. In this stage, a first aligning mark 36 is formed, in the same manner as the metal electrode layer. The substrate surface now appears as shown in Fig. 5, with a two-layer (gold and chromium) metal electrode layer 34 deposited, together with first aligning mark 36.

A conductive transparent film of indium oxide or tin oxide is now formed over the entire surface of the glass substrate, over the metal electrode layer 34. Etching is then performed on this transparent conductive layer, to form a lead electrode layer 16 and transparent display electrode layer 12 on the substrate surface, this pattern having the form shown in Fig. 6. As a result of these steps, a patter of multi-layer lead electrodes and of transparent display electrodes 12 is formed, together with the first and second aligning marks 36 and 38, as shown previously in Fig. 4. The aligning marks 36 and 38 enable the alignment of the metal electrode layer 34 with the transparent lead electrode layer 12 to be accurately performed, using mask alignment equipment for this purpose, which enables alignment to be performed to an accuracy of a few microns.

In this way, a multi-layer lead electrode structure having an electrical resistance considerably smaller than that obtainable with thin-film lead cell according to the present invention will now be described, with reference to Fig. 7. In this embodiment, a two-layer structure composed of a lower layer of chromium 34-a and an upper layer of gold 34-b is used for the metal electrode portion of each multi-layer lead electrode. However, only the gold layer 34-b is etched, and the chromium layer 34-a is left covering the entire surface of the cell substrate. The chromium layer may be held to a thickness of less than about 20 or 30 angstroms, in order to be transparent, or, if transparency is not necessary can be made about 200 angstroms. The chromium film can be made non-conductive by heat treatment, to cover it to chromium oxide film, after etching of the gold film has been performed. Subsequently, the lead electrode layer and display electrodes can be formed by depositing and etching a thin conductive film on the gold and chromium layers, as described for the first embodiment of the present invention. Thus, this second embodiment enables a simplification in manufacturing to be achieved, since it is not necessary to perform etching of the chromium layer.

A third embodiment of the present invention is shown in Fig. 8. This is a liquid crystal display cell having transparent electrodes 12 in the form of small rectangles, constituting a dot-matrix array of display electrodes. Each of the lead electrodes connecting the three sets of display electrode dots shown is a multi-layer lead electrode composed of a metal electrode layer 34 formed as described for the first or second embodiments above, and a thin-film lead electrode layer 16. Only the display electrode pattern of one substrate is shown in Fig. 8. Multi-layer lead electrodes in accordance with the present invention may also be utilized to connect the display electrodes of the opposite substrate, which are not shown in Fig. 8.

Referring now to Fig. 9, a fourth embodiment of the present invention is shown. Numeral 34 and 16 denote the metallic electrode layer and lead electrode layer respectively of a multi-layer lead electrode formed as described in accordance with the first or second embodiments above. The spacing between each of the lead electrodes is very small, of the order of 30 microns or less. Such a small spacing can result in leakage currents flowing between adjacent lead electrodes, causing deleterious effects upon the liquid crystal display. to prevent the flow of such leakage currents, therefore, a transparent insulating layer 40 is formed over and between the lead electrodes. This transparent insulating layer can be formed over portions of the substrate where lead electrodes become closely spaced together, by a masking technique, as described hereinafter. The transparent insulating layer can be composed of a material such as aluminum oxide Al_2O_3, silicon oxide SiO_2, silicon nitride Si_3N_4, etc. The thickness of the transparent insulating layer 40 can be of the order of 0.1 to 3 microns.

Fig. 10 is a diagram illustrating in cross-section

comprising a transparent insulating layer formed over and between said plurality of lead electrodes.

6. The improvement according to claim 5, in which said transparent insulating layer is formed from a substance selected from a group including Al_2O_3, SiO_2, and Si_3N_4.

7. The improvement according to claim 5, and further comprising a transparent coating layer formed between said transparent insulating layer and said plurality of lead electrodes.

8. The improvement according to claim 7, in which said transparent coating layer is composed of SiO_2.

9. The improvement according to claim 6, in which said transparent insulating layer has a thickness which is in the range of 0.1 to 3 microns.

10. The improvement according to claim 8, in which said transparent coating layer has a thickness which is in the range of 200 to 800 Angstroms.

11. A liquid crystal display cell substantially as shown and described with reference to the accompanying drawings.

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